FILE COPY

PIBS 1850e

SUMMARY OF FOLIAR ASSESSMENT SURVEYS FOR OXIDANT INJURY TO FIELD CROPS IN SOUTHERN ONTARIO 1991 - 1994

OCTOBER 1996

Ontario

Ministry of
Environment
and Energy

ISBN 0-7778-3931-8

SUMMARY OF

FOLIAR ASSESSMENT SURVEYS

FOR OXIDANT INJURY TO FIELD CROPS

IN SOUTHERN ONTARIO

1991-1994

OCTOBER 1996

Cade publication technique
n'est disponible qu'en anglais.

Copyright: Queen's Printer for Ontario, 1996
This publication may be reproduced for non-commercial purposes
with appropriate attribution.

PIBS 1850E01

SUMMARY OF

FOLIAR ASSESSMENT SURVEYS

FOR OXIDANT INJURY TO FIELD CROPS

IN SOUTHERN ONTARIO

1991-1994

Report prepared by:

R. Emerson
Phytotoxicology Section
Standards Development Branch
Ontario Ministry of Environment and Energy

TABLE OF CONTENTS

	Page No.
EXECUTIVE SUMMARY	3
A: INTRODUCTION	4
B: SURVEYS ON WHITE BEAN	4
a) Background	4
b) Methods	4
c) Results	6
C: SURVEYS ON TOMATO	8
a) Background	8
b) Methods	8
c) Results	9
D: SURVEYS ON POTATO	10
a) Background	10
b) Methods	10
c) Results	11
E: RESULTS OF LABORATORY EXAMINATIONS	11
F: AMBIENT OZONE CONCENTRATIONS	12
G: SUMMARY	12
Literature Cited	13

EXECUTIVE SUMMARY

Assessment surveys for ozone injury to field crops have been conducted by MOEE Phytotoxicology staff annually since 1971 to determine the degree and extent of injury each year to sensitive crops across southern Ontario. This report summarizes the more recent survey results from 1991 through 1994.

Foliar inspections for ozone injury were conducted annually on white beans in August from 1991 to 1994, and on tomatoes and potatoes in July from 1991 to 1993. All of these crops are known to be sensitive to ozone. Variety trial plots at experimental stations were examined each year, as well as some commercial plantings in 1993.

Every year, ozone injury was observed on the foliage of sensitive white bean, tomato and potato plantings at most stations. The most severe injury generally was observed each year on white beans, which is one of the most sensitive field crops to ozone. Injury ranging from trace to severe was observed on affected white bean plants each year. The overall injury index scores were severe in 1991 and 1994, as was the case in only three other years since 1971 (1976, 1984 and 1990). The injury ranked as light overall in 1992 and moderate in 1993. The ozone injury severity on white beans has varied annually and, on average, has been light or moderate in most years. In addition, ozone injury to tomatoes and potatoes was slightly increased in recent years compared to most of the 1980s. In spite of this, the severity of ozone injury to tomato and potato plantings across southern Ontario was found to be light overall in July from 1991 to 1993.

The foliar survey results for 1991 through 1994, together with the ambient ozone data, show that the ambient ozone levels encountered during the growing season each year were injurious to sensitive field crops in southern Ontario.

Summary of Foliar Assessment Surveys For
Oxidant Injury To Field Crops in Southern Ontario
1991 - 1994

A: INTRODUCTION

Ozone has long been recognized as the major component of the photochemical oxidant complex and as one of the most damaging of all air pollutants affecting vegetation. Ozone is commonly associated with urban atmospheres due to precursor pollutants in these areas. However, its presence is now known to extend into rural and uninhabited areas as a result of long range transport by regional air movements. In southern Ontario, high ozone levels are generally associated with regional southerly air flows which are carried across the lower Great Lakes after having passed over numerous urban and industrialized areas of the United States. Contributing to this influx pattern are the localized, domestic downwind urban effects which can add to the already high background levels.

In an effort to assess and compare the annual severity of foliar ozone injury on sensitive Ontario crops (eg., white beans, tomatoes, potatoes), personnel of the Phytotoxicology Section have conducted visual assessment surveys throughout the major crop production areas in southern Ontario since 1971. The results of the earlier (1971-1990) surveys have been discussed in previous MOEE reports (ARB-89-83-Phyto; ARB-212-90-Phyto). This report summarizes the results of the more recent surveys from 1991 through 1994. The extent of the assessment coverage and the crops and number of varieties examined each year are shown in Table 1.

B: SURVEYS Of WHITE BEAN

a) Background

Bronzing of the foliage of white beans has been observed in Ontario since 1918 and was originally classed as a non-parasitic disease and referred to as sunscald. However, it was not until 1968, following extensive field work in 1965 and 1967, when the bronzing disorder was more thoroughly documented and was found to be associated with elevated levels of tropospheric ozone. The bronzing of foliage develops in the period between flowering and normal senescence, with older leaves becoming senescent and abscising prematurely. Younger, fully expanded leaves develop a bronze/black-coloured necrotic stipple on the upper surface .

Since 1971, white bean crops in the major production areas of Ontario have been annually inspected for ozone injury by Phytotoxicology staff, with the exception of 1988 and 1989.

b) Methods

In late August each year (1991-1994), foliar inspections for ozone injury were conducted in the white bean variety trials at the OMAFRA (Ontario Ministry of Agriculture, Food, & Rural Affairs) and CDA (Canada Department of Agriculture) experimental stations at Harrow (CDA), Ridgetown (OMAFRA) and Huron Park (OMAFRA). The white bean variety trial plots at the University of Guelph Elora experimental station also were inspected annually (see Figure 1). Photographs were taken of the ozone symptoms and/or specimens of injured leaves were collected for storage in the

Phytotoxicology Section's herbarium. A sample of injured foliage (Ex Rico variety) was collected at Huron Park in 1994 and returned to the Phytotoxicology Section for examination by the Section's histopathologist.

In assessing the white bean plants for ozone injury at the experimental stations, foliage was inspected on numerous varieties, including recommended varieties for Ontario. The plants inspected in each variety plot were evaluated for foliar ozone damage (stippling/bronzing) and a numerical injury rating (from 0 to 6) was assigned that represented the average severity of injury to the plot. As plant sensitivity to ozone is largely influenced by stage of development, plant maturity also was evaluated and numerically rated from 1 to 7. Described below are the injury and maturity rating categories.

INJURY SEVERITY

Rating	*Criteria*
0	*No oxidant symptoms observed*
1	*Scattered stippling on a few of the oldest leaves*
2	*Scattered stippling over most of the leaves*
3	*Moderate stippling or bronzing over a few of the leaves*
4	*Moderate stippling or bronzing over most of the leaves with some coalescence into flecks*
5	*Severe stippling or bronzing coalescing into necrotic flecks on many of the leaves; some premature leaf senescence and initial defoliation*
6	*Severe stippling or bronzing and coalescence on almost all leaves; plants prematurely senescent and defoliation occurring*

STAGE OF PLANT DEVELOPMENT

Stage	*Description*
1	*Plant foliage completely green; most pods are quite thin with beginning of bean development; flowers still evident and numerous 1-2 cm developing pods*
2	*Plant foliage completely green; most pods are quite thin with initial stage of bean development; no flowers remaining but still numerous immature pods (no beans)*
3	*Plant foliage mostly green with some gradual chlorotic development, pods are green with oldest ones almost to full size; youngest pods have bean formation but are still quite thin*
4	*Plant foliage approximately 50% chlorotic; older pods are starting to turn yellow; youngest pods still green but have beans that are approximately 50% developed*

5 *Most leaves appear chlorotic with only a green hue to the plants; most pods have turned yellow and have indented between the beans; still some fully developed green pods at the top*

6 *Leaves beginning to abscise - mostly yellow; pods mostly yellow in colour and leathery in texture; bean development mostly complete but beans still with 20-30% moisture*

7 *Leaves have almost totally abscised; pods yellow and dry with completely dry and mature beans (pods rattle when shaken)*

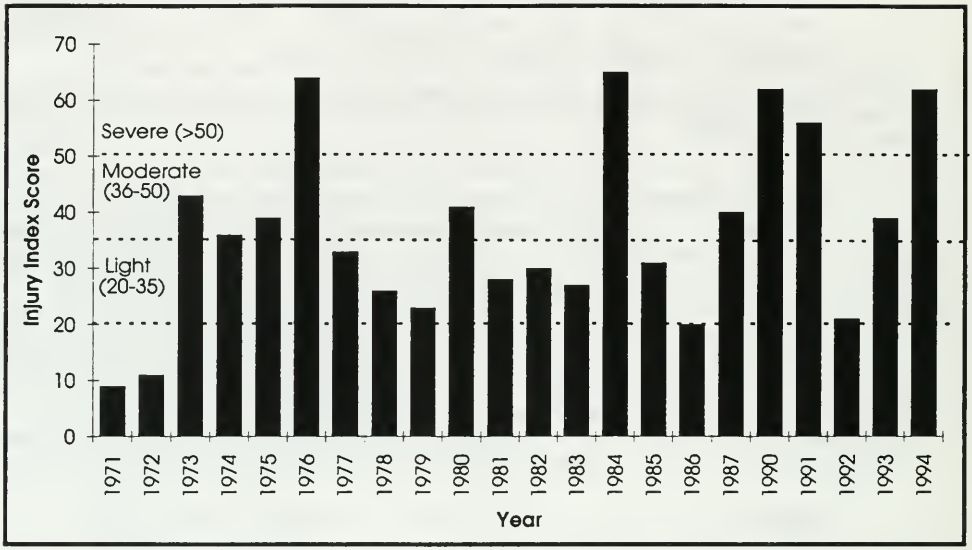
The seven injury rating levels previously described fall into five injury severity categories: no injury (0), trace (rating 1), light (ratings 2-3), moderate (rating 4) and severe (ratings 5-6). In order to compare the overall severity of ozone bronzing/stippling on white beans between locations and years, an injury severity index was devised. For each location/year, the total number of injury ratings (observations) was tallied and the percentage of ratings in each injury category (trace, light etc.) was calculated. The percentage values (decimal) were then multiplied by a corresponding weighting factor - trace: 5; light: 10; moderate: 50; and severe: 100. Then, the separate indices were added to generate a total injury severity index score for each location (Table 2) and year (Table 3). The higher the index score, the higher the number of ratings in the more severe injury categories. For purposes of interpretation, a score between 1 and < 20 is classed as trace; between 20 and 35 light; and between 36 and 50 moderate. A score of greater than 50 is classed as severe.

c. Results

The inspections in late August each year (1991-1994) revealed ozone injury (bronzing/stippling) on white bean foliage at all experimental stations. The severity of foliar injury each year ranged from trace to either moderate or severe. In 1994, the white bean plants at Ridgetown and Harrow were in an advanced stage of maturity. Most plots at Harrow were retaining only some original leaves, while the plots at Ridgetown were almost 100% defoliated. Because of this, these stations could not be accurately assessed for ozone and, in turn, results are not shown for the Harrow and Ridgetown stations in 1994. Nevertheless, these locations had injury resembling ozone on most plants that still retained some original leaves, with most of these leaves having moderate or severe injury.

Table 2 shows that the injury severity scores varied between locations and years. The injury index score was severe (> 50) at Harrow in 1992, at Ridgetown in 1993, at Huron Park in 1991 and 1994, and at Elora in 1991, 1993 and 1994. The overall injury index for all locations ranked as severe in 1991(56) and 1994 (62). These scores, compared to those for the earlier surveys dating back to 1971 (Tables 3 and 4), were similar to the high scores in 1976 (64), 1984 (65), and 1990 (62). In all other years, the severity of ozone injury to white bean crops was either trace, light or moderate overall. The 1992 and 1993 injury scores fell in the light and moderate categories respectively. The annual injury index scores since 1971 are graphically illustrated in Figure 2. It is apparent that the severity of ozone injury on white bean plantings has been variable over the years.

Figure 2: Annual Severity of Ozone Injury to White Bean Plantings Since 1971.



Statistical analyses were performed on the 1991 through 1994 injury and maturity ratings for the varieties recommended for Ontario. These varieties were Centralia, Crestwood, Dresden, Envoy, Ex Rico 23, Fleetside, Harowood, Midland, Mitchell, Rocket, OAC Cygnus, OAC Gryphon, OAC Laser, OAC Rico, OAC Seaforth, OAC Speedvale, OAC Sprint, Schooner, Shetland, Stinger, Vista and Wesland. The correlation coefficient for the combined data from all years/locations (excluding Harrow and Ridgetown in 1994) showed a good correlation between injury and plant maturity, with the r value of 0.73 being highly significant ($p < 0.01$). In addition, Duncan's Multiple Range Test was performed to determine if there was any difference in injury severity between locations. This test was performed on all recommended varieties, as well as only on the varieties that were common to all locations each year. The Analysis of Variance results in Table 5 show that there was a significant difference in injury between locations in all years except 1993. The table also shows good agreement between the Analysis of Variance results for all recommended varieties and the common varieties.

The largest number of varieties were inspected each year at Huron Park and Elora. At these stations, most white bean varieties each year were injured, but some varieties displayed more or less ozone injury than others. The varieties that consistently displayed the most severe injury at both locations were Mitchell, OAC Seaforth, and OAC Speedvale. The varieties with the least injury were Crestwood, Harowood, and Vista.

C: SURVEYS ON TOMATO

a) Background

Tomato plantings have been assessed for oxidant injury on a regular annual basis from 1972 through 1993. The survey was discontinued in 1994. The surveys began in Ontario following the report of unusual symptoms to commercial tomato crops in southwest Ontario in 1972. The injury was noticed by field representatives from the research division of a major canning company and samples were submitted to the Department of Plant Pathology, University of Guelph. After ruling out any disease problems, the Phytotoxicology Section was notified and field investigations/surveys followed. The symptomology was found to be typical of reports of PAN (peroxyacetyl nitrate) injury in the literature and has been called PAN-type injury in previous reports. To explore the cause of the injury, a number of field and laboratory experiments, using an anti-ozonant chemical protective spray, were conducted during 1978 through 1981 by Phytotoxicology personnel. From the results of this work, it was concluded that the injury was caused by ozone rather than PAN. In 1994, because of budget and program cutbacks, the field crop ozone injury assessment program was reviewed and a decision was made to discontinue the July surveys on tomato and potato.

Ozone injury on tomatoes occurs initially on the lower leaf surface as bronze, copper or grey-coloured lesions. The lesions usually are small and circular and can coalesce and become bifacial resulting in larger irregular shaped lesions on both surfaces. Ozone also can result in glazing (glassy appearance) on the under surface. The lesions may be scattered across the lower (abaxial)-leaf surface, or be confined near the tip, base, or margins of the leaf blade. Moreover, the injured compound leaves often show a pattern of similar-aged tissue/leaflets being affected (eg., opposite leaflets with injury at tip, base or margins). The injury usually is more pronounced on middle-aged and older compound leaves.

b) Methods

The ozone injury assessment survey on tomato was conducted each year (1991-1993) in early to mid-July. In 1991 and 1992, the foliar inspections for ozone injury were confined to the cultivar trials at the experimental stations at Harrow (CDA), Ridgetown (OMAFRA), Simcoe (OMAFRA), and Smithfield (CDA). In 1993, the Smithfield station discontinued the experimental tomato trials and commercial tomato plantings off-site were examined in the area. Also in 1993, a few commercial tomato fields were inspected in the Chatham and Dover areas because of OMAFRA reports of ozone injury on tomatoes in these areas. A few experimental tomato cultivars at the Kemptville OMAFRA station also were examined in 1993 (see Figure 1). In all years, photographs were taken of the ozone injury and/or specimens of injured leaves were collected in a plant press for storage in the Section's herbarium. Also, in 1992, tomato foliage was collected from the Smithfield station and returned to the Phytotoxicology Section for examination by the Section's pathologist.

Normally, at each location, foliage was inspected for ozone injury on two representative plants (main shoots) of each cultivar, and the average injury (%) to each compound leaf was determined. The average injury to each plant was calculated using the formula A/B x C, where A = the number of injured leaves; B = the total number of examined leaves, and C = the average injury to all affected leaves.

c) Results

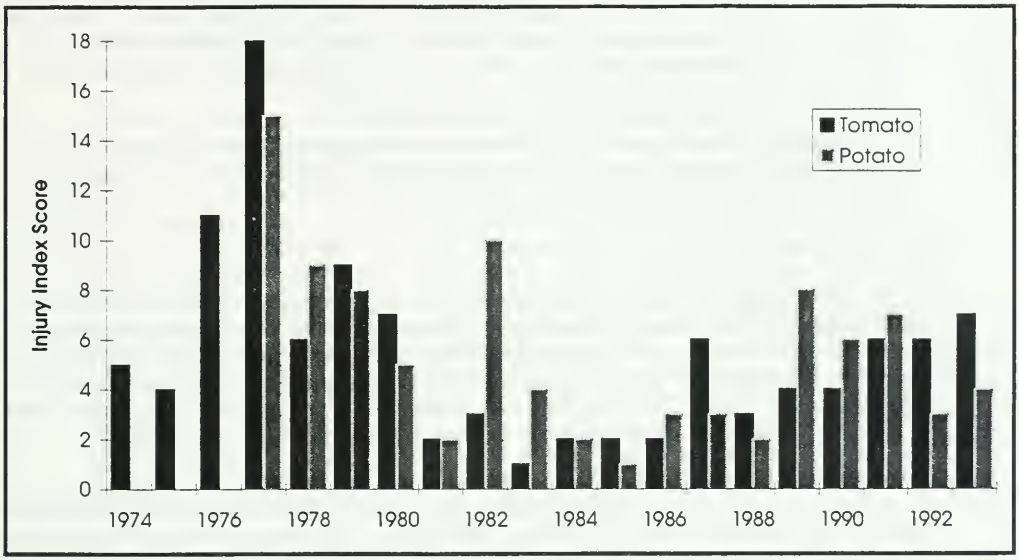
The results of the regular July surveys on tomatoes (1991-1993) are summarized in Tables 1, 6, and 7. Table 6 shows the percentage of observations in each of the five injury categories (none, trace, light, moderate, severe), and the corresponding total injury index score for each of the experimental stations each year. The injury at the Harrow, Ridgetown and Simcoe stations each year fell into the no injury (none), trace and/or light injury categories, with Ridgetown having light injury on most plants in 1993. The examined tomato plants at the Kemptville station had no injury in 1993. In 1991, trace to light injury also was observed on the tomato plants examined at the Smithfield station. In 1992, the tomato trials at Smithfield were too severely diseased to be accurately assessed for ozone injury (see Section D) and there were no varietal trials in 1993. The commercial tomato plantings examined in the Chatham and Dover areas in 1993 had trace to light injury. In addition, trace ozone was observed on one of the two commercial sites inspected in the Smithfield area in 1993.

The tomato varieties with the most severe ozone injury on the foliage (1991-1993) were H 1790, Ohio 8245, Peto 696, Summerset and Stokes Pak. In previous years (1983-1990), the experimental plantings most severely affected were FM 6203, H 2653, Jackpot, Ohio 7814, Ont 4240, Pik Red, Simcoe and Stokes Pak.

Tables 6 and 7 show that the total injury severity index scores varied among the experimental stations from year to year. The highest injury severity scores were detected at Smithfield in 1991, at Simcoe and Ridgetown in 1992, and at Ridgetown in 1993. A comparison of the injury ratings between the varieties that were common to these experimental stations further suggested that these were the most severely affected locations. Table 7 shows that the injury index over all locations (based on all observations) each year was similar (range 6-7), with the injury in 1993 being slightly more severe than in 1991 and 1992. Compared to the highest possible score, these scores are very low and reflect very light injury.

Figure 3 shows that the severity of ozone injury to tomatoes across southern Ontario peaked in the late 1970s, was minimal in the mid 1980s and was increased slightly again in recent years (1991-1993). In most years, the severity of ozone injury to tomato plantings across southern Ontario has been very light overall at the time of the surveys.

Figure 3: Severity of Ozone Injury Observed on Tomato and Potato Plantings Since 1974.



D: SURVEYS ON POTATO

a) Background

Potatoes have been inspected for foliar injury by ozone by Phytotoxicology staff on an annual basis from 1977 to 1993. The annual survey on potatoes was conducted at the same time as the tomato survey in early to mid-July. In 1994, the potato survey was discontinued.

Ozone injury to potato foliage can occur on both upper and lower surfaces. The symptoms on the upper surface appear as blackened stipples or flecks which can coalesce and become bifacial. The symptoms on the undersurface appear as irregularly-sized, silver-grey lesions which also can become bifacial and coalesce as they increase in size and severity. The lower surface symptoms very closely resemble those that have been documented on tomato foliage. The foliar symptoms usually appear sometime between late June to mid-July when the plants have flowered and the tubers are developing. As the demands for photosynthetically-produced compounds at this time are at their peak, the potential for adverse yield effects is enhanced.

b) Methods

The potato inspections each year (1991-1993) were conducted in the varietal trials at the OMAFRA experimental stations at Simcoe, Cambridge, Kettleby and Kemptville. In 1991 and 1992, the CDA potato trials at the University of Western Ontario research farm near London also were

inspected. In 1993, these trials were moved back to their original location at Ridgetown. In 1993, the variety trial plot at the Kettleby station had been discontinued and only a single cultivar (Yukon Gold) was inspected there. Because of this, a few off-site potato plantings in the Kettleby area also were examined in 1993. In all years, photographs were taken of the ozone injury and/or specimens of injured leaves were collected for storage in the Section's herbarium.

The injury evaluation method was identical to the one used on tomato. All leaves were examined on the main vine(s) of one to two representative plants per variety and the average injury to each plant was calculated and expressed in percent.

c) Results

The observations from the regular potato surveys in July each year (1991-1993) are summarized in Tables 1, 7 and 8. Ozone injury on affected leaves was predominant on the under surface. All of the observations at the experimental stations are summarized in Table 8. With few exceptions, the severity of ozone injury to potato foliage at all experimental stations each year was either trace or trace to light. The exceptions were Ridgetown, where a few plants had moderate injury in 1993, and Kettleby and Kemptville, where no injury was apparent in 1992 and 1993. The commercial plantings inspected near Kettleby in 1993 also were injury-free.

Tables 7 and 8 show that the injury index scores varied among the experimental stations, with London having the most severe injury in two (1991/1992) out of the three years. In 1993, the highest injury index score (based on all observations) was shared by Simcoe and Ridgetown. A comparison of the injury between only the varieties that were common to all stations verified that the potato plants at the London station had the most severe injury in 1991 and 1992. In 1993, the common varieties had the most severe injury at Simcoe. Table 7 shows the annual injury index over all locations between 1991 and 1993. 1991 had the highest injury index score (7), followed by 1993 (4). However, these values are quite low compared to the highest possible score (100) and reflect very light injury.

During 1991 to 1993, the varieties with the most severe injury were Chieftain, Eramosa, Norland, Shepody and Yukon Gold. The most severe injury was observed on Norland (13%), followed by Yukon Gold (7%) and Shepody (3%). In previous years (1983-1990), the varieties Denali, Eramosa, Gold Rus, Jemseg, Rose Gold and Viking also were found to be sensitive. Overall, Norland is the most sensitive to ozone.

Figure 3 on page 10 shows that the severity of ozone injury to potatoes across southern Ontario was more severe in the late 1970s, was minimal in the mid 1980s and was increased slightly again in recent years, particularly from 1989 to 1991. In most years, the severity of ozone injury to potato plantings across southern Ontario was very light overall at the time of the surveys.

E: Results of Examinations in Laboratory

The white bean foliage sampled at Huron Park in 1994 had intervienal coalescent injury and appeared scorched. The results of the histopathological examination revealed that the foliar injury was typical of ozone.

The pathology results revealed that common diseases (leaf spot, *Septoria lycopersici;* and leaf blight, *Alternaria solani*) had caused the tomato foliage injury at Smithfield in 1994.

F: Ambient Ozone Concentrations

Summarized in attached Tables 9 and 10 are the ambient ozone levels that were recorded in southern Ontario just prior to the surveys on white beans, tomatoes and potatoes.

Table 9 shows that, in the white bean production areas, ambient ozone levels were, at times, at or above the MOEE's 80 ppb hourly criterion during July and/or August each year (1991-1994), with the exceptions being Parkhill, Merlin, and Guelph in 1992, and Guelph in 1993. This criterion was established to protect vegetation, and ambient ozone levels greater than the 80 ppb criterion are potentially injurious to sensitive crops. On the basis of the total number of hours with 80 ppb or more ozone at all monitoring stations, 1991 was by far the worst year (99 hrs.), followed by 1994 (15 hrs.), 1993 (11 hrs.) and 1992 (1 hr.). The hour value shown for 1994 likely would have been higher if the instrument malfunction at Windsor had not occurred in August. Over these four years, 1991 and 1994 also were the worst years for ozone injury to white bean plantings (based on all sites), followed by 1993 and 1992. In 1992, only a single hour with 82 ppb ozone was recorded at the four air monitoring stations shown in Table 9, and ozone injury to white bean crops overall was less severe (light overall) than in 1991, 1993 and 1994.

Table 10 summarizes the ambient ozone levels recorded in June and July in the vicinity of the 8 experimental stations where tomato and/or potato plants were inspected in July each year (1991 to 1993). This table shows that the MOEE's hourly criterion of 80 ppb had been exceeded at times in all areas prior to the tomato/potato surveys, with exception of Simcoe in 1991, Stouffville and Peterborough in 1993, and Ottawa in 1991 through 1993. The number of exceedances of the 80 ppb criterion varied between stations and years. The largest number of exceedances occurred in 1991 at most stations, particularly at Merlin (30), Windsor (16), London (14), Kitchener (12) and Peterborough (9). The most severe injury to potato crops overall also was observed in 1991. Compared to 1991, there were fewer exceedances of the MOEE criterion in 1992 and 1993, with Simcoe having the largest number (9), followed by Windsor (8) and Merlin (6, 5). Tomato plantings at Simcoe and Ridgetown (near Merlin) were the most severely injured in 1992 and 1993. These stations also had the most severe injury to potato foliage in 1993 (Table 8).

In all years (1991 to 1993), ozone injury to tomato and potato plantings across southern Ontario was found to be very light overall, even in 1991 which had the greatest number of exceedances of the MOEE's 80 ppb criterion. This suggests that the plants, especially in 1991, were not highly sensitive at the time of the ozone episodes. Plant sensitivity to ozone and injury severity are influenced by several factors (eg., air temperature, humidity, sunlight, soil moisture, soil nutrient levels, crop, variety and stage of growth).

G: SUMMARY

During the regular July and August surveys (1991 to 1994), ozone injury was observed on the foliage of white bean, tomato and potato plantings at locations across southern Ontario. Each year, injury in the trace to severe range was observed on the foliage of white beans, which is one of the most ozone-sensitive crops. The overall injury scores were severe in 1991 and 1994 (as in 1976, 1984 and 1990), light in 1992, and moderate in 1993. Since 1971, injury on inspected white bean plantings has varied annually and has been light or moderate overall in most years.

Ozone injury to tomato and potato plantings also has varied annually, slightly increasing

overall in recent years compared to other years since 1983. The overall annual injury index scores have reflected very light injury to tomato and potato plantings in most years.

Every year (1991-1994), ambient ozone levels above the MOEE's (80 ppb/hr) criterion were recorded in southern Ontario prior to the surveys. The foliar surveys confirm that the ozone concentrations during the growing season each year had been injurious to sensitive field crops in southern Ontario.

Literature Cited

1) MOEE Report ARB-89-83-Phyto: Summary of Foliar Assessment Surveys for Oxidant Injury to Field Crops in Southern Ontario - 1971-1982

2) MOEE Technical Memorandum HCB-103-3512-93: Ozone Injury Survey on Tomato and Potato (1993) - Some Preliminary Observations.

3) MOEE Report ARB-212-90-Phyto: Summary of Foliar Assessment Surveys for Oxidant Injury to Field Crops in Southern Ontario - 1983-1990

Figure 1: Experimental Stations and Air Monitoring Locations Cited in Report

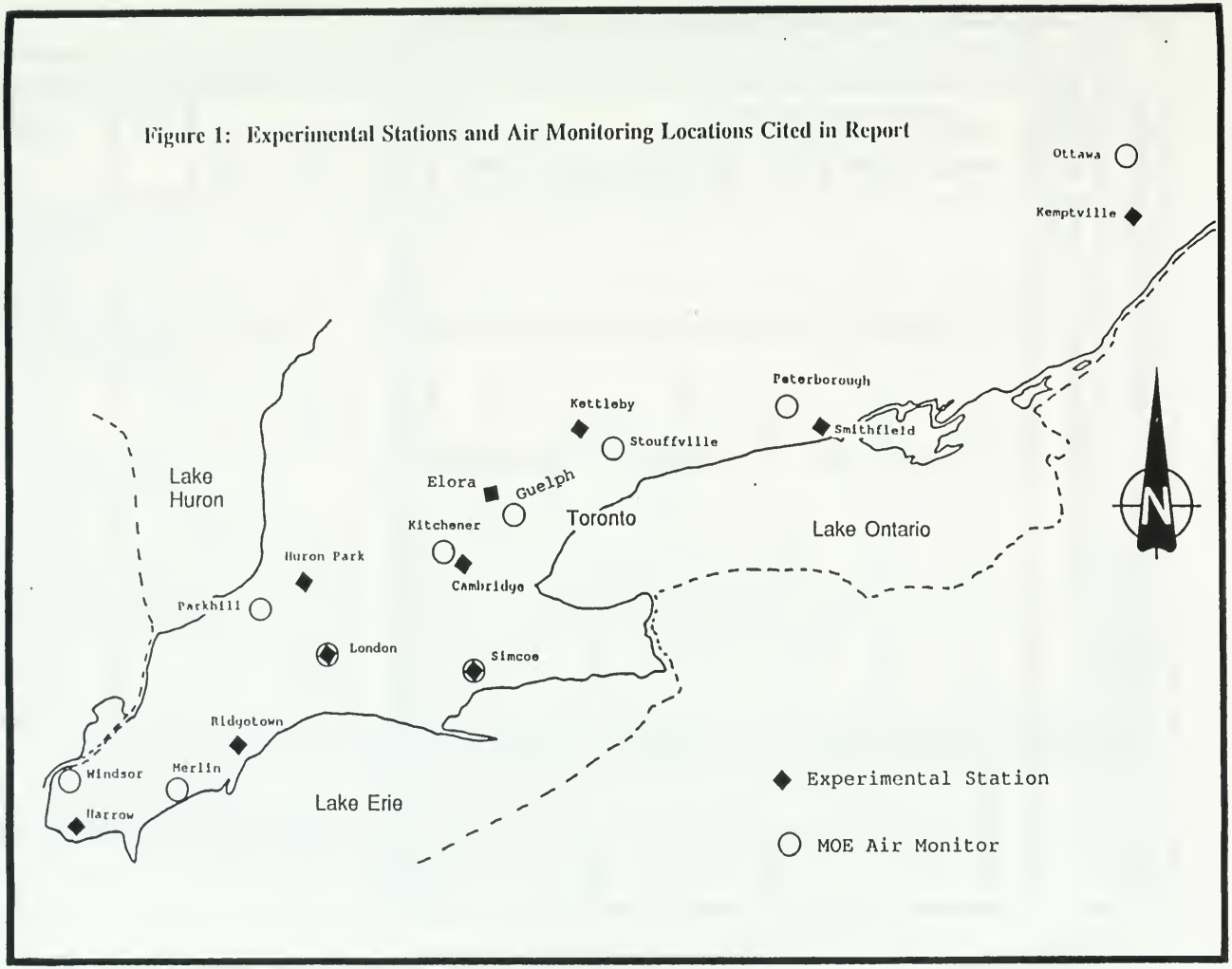


Table 1: Summary of Crops, Total Number of Observations, and Crop Varieties Examined Each Year: 1991 to 1994.

Crop	Total Visual Examinations	Number of Different Varieties Inspected
White Bean		
1991	106	46
1992	138	45
1993	60	23
1994	101	42
Tomato		
1991	87	32
1992	59	29
1993	81	30
Potato		
1991	87	17
1992	81	17
1993	89	15

Note: The above summary includes any commercial plantings that were inspected.

Table 2: Severity of Ozone Injury to White Bean Foliage at the CDA and OMAFRA Experimental Stations Visited in Southern Ontario from 1991 to 1994.

Location, Year (Day)	Total Obs.	Percentage (%) Observations in Each Injury Category					Corresponding Injury Index Scores* (Weighting Factor is Shown in Parenthesis)				Total Injury Index Score**
		None (0)	Trace (1)	Light (2, 3)	Moderate (4)	Severe (5, 6)	Trace (x5)	Light (x25)	Moderate (x50)	Severe (x100)	
Harrow (CDA Station)											
1991 (Aug. 27)	12	0	8.3	66.7	25	0	0.4	16.7	12.5	0	**30**
1992 (Aug. 25)	14	0	0	0	57.1	42.9	0	0	28.6	42.9	**72**
1993 (Aug. 27)	10	0	0	60	30	10	0	15	15	10	**40**
1994 (Aug. 31)	11	NR	NR	NR	NR	NR	NR	NR	NR	NR	**NR**
Ridgetown (OMAFRA Station)											
1991 (Aug. 27)	19	0	5.3	21.8	73.7	0	0.3	5.3	36.9	0	**43**
1992 (Aug.24)	42	4.8	47.6	26.2	21.4	0	2.4	6.6	10.7	0	**20**
1993 (Aug. 22)	7	0	0	14.3	71.4	14.3	0	3.6	35.7	14.3	**54**
1994 (Aug. 30)	9	NR	NR	NR	NR	NR	NR	NR	NR	NR	**NR**
Huron Park (OMAFRA Station)											
1991 (Aug. 28)	36	0	0	2.8	83.3	13.9	0	0.7	41.7	13.9	**56**
1992 (Aug. 25)	40	17.5	40	35	7.5	0	2	8.8	3.8	0	**15**
1993 (Aug. 24)	22	0.5	36.4	40.9	18.2	0	1.8	10.2	9.1	0	**21**
1994 (Aug. 30)	41	0	0	2.4	48.8	48.8	0	0.6	24.4	48.8	**79**
Elora (University of Guelph Station)											
1991 (Aug. 28)	39	0	2.5	7.7	46.2	43.6	0.1	1.9	23.1	43.6	**69**
1992 (Aug. 26)	42	11.9	42.9	42.9	2.3	0	2.1	10.7	1.2	0	**14**
1993 (Aug. 24)	21	0	14.3	19	38.1	28.6	0.7	4.8	19.1	28.6	**53**
1994 (Aug. 30)	42	0	4.8	33.3	38.1	23.8	0.2	8.3	19.1	23.8	**51**

* Injury indicies were derivad by calculating percantage (%) of observations in each injury catagory (relative to total observations), and then multiplying the percentage (decimal) valuas by the following corresponding weighting factors - trace (x 5); light (x 25); moderate (x 50) and severe (x 100). The total injury indax score for each location/year was the sum of all injury indices. For example, if 30% of plots fell in traca catagory (0.3 x 5 = 1.5), 30% in light (0.3 x 25 = 7.5), 20% in moderate (0.2 x 50 = 10) and 20% in severe (0.2 x 100 = 20), tha total injury index score was 1.5 + 7.5 + 10 + 20 = 39, out of a maximum 100.

** Valuas hava been rounded off to nearest whole number.

NR - No result as aithar several or all leaves abscised from plants

Table 3: Overall Annual Severity of Ozone Injury to White Beans In Southern Ontario From 1971 to 1994.

Year	Total Obs.	Percentage (%) Observations In Each Injury Category					Corresponding Injury Index Scores** (Weighting Factors are Shown In Parenthesis)				Total Injury Index Score***
		None (0)*	Trace (1)*	Light (2-3)*	Moderate (4)*	Severe (5-6)*	Trace (x5)	Light (x25)	Moderate (x50)	Severe (x100)	
1971	21	71	5	14	10	0	0.3	3.5	5	0	**9**
1972	43	62	19	9	5	5	1.0	2.3	2.5	5	**11**
1973	50	4	8	32	42	14	0.4	8	21	14	**43**
1974	33	6	15	37	33	9	0.8	9.3	16.5	9	**36**
1975	39	8	8	48	18	18	0.4	12	9	18	**39**
1976	54	0	7	19	30	44	0.4	4.8	15	44	**64**
1977	28	4	14	42	36	4	0.7	10.5	18	4	**33**
1978	11	9	18	46	27	0	0.9	11.5	13.5	0	**26**
1979	13	0	40	30	30	0	0.2	7.5	15	0	**23**
1980	21	0	14	38	33	14	0.7	9.5	16.5	14	**41**
1981	17	0	12	65	23	0	0.6	16.3	11.5	0	**28**
1982	48	2	23	44	27	4	1.2	11	13.5	4	**30**
1983	21	14	14	48	19	5	0.7	12	9.5	5	**27**
1984	36	3	6	19	25	47	0.3	4.8	12.5	47	**65**
1985	61	13	16	41	20	10	0.8	10.3	10	10	**31**
1986	191	13	35	37	12	3	1.8	9.3	5.5	3	**20**
1987	212	0	13	39	38	10	0.7	9.8	19	10	**40**
1990	122	2	11	17	25	45	0.6	4.3	12.5	45	**62**
1991	106	0	3	15	61	21	0.2	3.8	30.5	21	**56**
1992	138	10	39	31	15	4	2	7.8	7.5	4	**21**
1993	60	2	18	33	33	13	0.9	8.3	16.5	13	**39**
1994	83	0	2	18	43	36	0.1	4.5	21.5	36	**62**

* Corresponding numerical injury rating utilized from 1975 to 1994

** Calculated by multiplying percentage value (decimal) by assigned weighting factor for each injury category and adding the 4 values for a "Total Injury Index Score" (out of a maximum 100) (i.e. 15% in trace = 0.15 x 5 = 0.75).

*** Values have been rounded off to nearest whole number.

Note: Surveys were not conducted in 1988 and 1989, and 1994 data excludes Harrow and Ridgetown.

Table 4: Comparison of Annual White Bean Foliar Injury Index Scores from 1971 to 1994.		
Year	**Total Annual Injury Index Score**	**Severity Category**
1984	65	Severe (> 50)
1976	64	
1990	62	
1994	62	
1991	56	
1973	43	Moderate (36 - 50)
1980	41	
1987	40	
1975	39	
1993	39	
1974	36	
1977	33	Light (20 - 35)
1985	31	
1982	30	
1981	28	
1983	27	
1978	26	
1979	23	
1992	21	
1986	20	
1972	11	Trace (< 20)
1971	9	

Table 5: Comparison of Ozone Injury Severity to White Bean Foliage by Location (order of highest to lowest injury index scorers): 1991 to 1994.

Duncan's Multiple Range Test	Year / Location							
	1991		1992		1993		1994	
	All Varieties*	Common Var.**	All Varieties*	Common Var.**	All Varieties*	Common Var.**	All Varieties*	Common Var.**
	Elora a,b	Huron Pk. a	Harrow a	Harrow a	Ridgetown a	Ridgetown a	Huron Pk. a	Huron Pk. a
	Huron Pk. a	Elora a,b	Ridgetown b	Ridgetown b	Elora a	Harrow a	Elora b	Elora b
	Ridgetown b,c	Ridgetown b,c	Huron Pk. b	Elora b	Harrow a	Elora a	NR	NR
	Harrow c	Harrow c	Elora b	Huron Pk. b	Huron Pk. b	Huron Pk. a	NR	NR
F Value	6.40***	6.33***	17.23***	18.92***	5.15***	1.89^{NS}	9.07***	9.07***

* All named varieties recommended by OMAFRA. ** Recommended varieties common each year at all locations. In 1994, Avanti was included due to a low number of common varieties. *** Highly significant ($p < 0.01$). NR - No results. NS - Not significant.
Note: Injury index values for locations followed by the same letter were not significantly different

Table 6: Severity of Ozone Injury to Tomato Foliage at the Experimental Stations Inspected in Southern Ontario: 1991 to 1993.

Location, Year (Day)	Total Obs.	Percentage (%) Observations in Each Injury Category					Corresponding Injury Index Scores* (Weighting Factor is Shown in Parenthesis)				Total Injury Index Score**
		None (0)	Trace (>0-1%)	Light (>1-10%)	Moderate (>10-35%)	Severe (>35%)	Trace (x5)	Light (x25)	Moderate (x50)	Severe (x100)	
Harrow (CDA Station)											
1991 (Jul. 10)	24	41.7	58.3	0	0	0	2.9	0	0	0	**3**
1992 (Jul. 7)	20	45	55	0	0	0	2.8	0	0	0	**3**
1993 (Jul. 7)	28	71.4	28.6	0	0	0	1.4	0	0	0	**1**
Ridgetown (OMAFRA Station)											
1991 (Jul. 10)	21	28.6	61.9	9.5	0	0	3.1	2.4	0	0	**6**
1992 (Jul. 8)	15	0	86.7	13.3	0	0	4.3	3.3	0	0	**8**
1993 (Jul. 6)	15	0	40	60	0	0	2	15	0	0	**17**
Simcoe (OMAFRA Station)											
1991 (Jul. 11)	22	0	91	9.1	0	0	4.6	2.3	0	0	**7**
1992 (Jul. 9)	24	25	54.2	20.8	0	0	2.7	5.2	0	0	**8**
1993 (Jul. 8)	20	20	70	10	0	0	3.5	2.5	0	0	**6**
Smithfield (CDA Station)											
1991 (Jul. 15)	20	5	65	30	0	0	3.3	7.5	0	0	**11**
1992 (Jul. 17)	NR	NR	NR	NR	NR	0	NR	NR	NR	NR	**NR**

* Injury index scores were derived by multiplying the percentage (decimal) values by the following corresponding weighting factors - trace (x 5); light (x 25); moderate (x 50) and severe (x 100). The total injury index score for each location/year was the sum of all injury indices. For example, if 30% of plots fell in trace (0.3 x 5 = 1.5), and 30% in light (0.3 x 25 = 7.5), the total injury index score would be 1.5 + 7.5 = 9, out of a maximum 100. ** Values have been rounded off to nearest whole number. NR - No ratings as plants were too diseased to assess accurately.

Table 7: Comparison of Ozone Injury Index Scores for Tomato and Potato Foliage Between Experimental Stations and Years: 1991 to 1993.

Location	Injury Index Score (Out of 100)		
	Tomato		
	1991	1992	1993
Harrow	3	3	1
Ridgetown	6	8	17
Simcoe	7	8	6
Smithfield	11	NR	NR
Overall (All Sites)*	**6**	**6**	**7**

Location	Potato		
	1991	1992	1993
Ridgetown	NR	NR	6
London	12	5	NR
Simcoe	5	2	6
Cambridge	3	4	2
Kettleby	8	0	0
Kemptville	6	0	0
Overall (All Sites)*	**7**	**3**	**4**

* All sites, including commercial plantings inspected in 1993.
NR - No data, tomato plants at Smithfield were diseased and unratable in 1992, and in 1993 the variety trials were discontinued at Smithfield. Where the potato data shows an NR, there were no potato trials that year.

Table 8: Severity of Ozone Injury to Potato Foliage at the Experimental Stations Inspected in Southern Ontario: 1991 to 1993.

Location, Year (Day)	Total Obs.	Percentage (%) Observations in Each Injury Category					Corresponding Injury Index Scores* (Weighting Factor Is Shown in Parenthesis)				Total Injury Index Score**
		None (0)	Trace (>0-1%)	Light (>1-10%)	Moderate (>10-35%)	Severe (>35%)	Trace (x5)	Light (x25)	Moderate (x50)	Severe (x100)	
Ridgetown (OMAFRA Station)											
1993 (Jul. 6)	22	45.5	45.5	4.5	4.5	0	2.3	1.1	2.3	0	**6**
London (University Research Station near Ilderton)											
1991 (Jul. 9)	20	10	55	35	0	0	2.8	8.8	0	0	**12**
1992 (Jul. 7)	25	12	84	4	0	0	4.2	1	0	0	**5**
Simcoe (OMAFRA Station)											
1991 (Jul. 11)	22	22.7	72.7	4.5	0	0	3.6	1.1	0	0	**5**
1992 (Jul. 9)	16	62.5	37.5	0	0	0	1.9	0	0	0	**2**
1993 (Jul. 8)	25	40	44	16	0	0	2.2	4	0	0	**6**
Cambridge (OMAFRA Station)											
1991 (Jul. 9)	23	52.2	43.5	4.3	0	0	2.2	1.1	0	0	**3**
1992 (Jul. 7)	24	58.3	33.3	8.3	0	0	1.7	2.1	0	0	**4**
1993 (Jul. 7)	22	86.4	9.1	4.5	0	0	0.5	1.1	0	0	**2**
Kettleby (OMAFRA Station)											
1991 (Jul. 8)	8	0	87.5	12.5	0	0	4.4	3.1	0	0	**8**
1992 (Jul. 6)	8	100	0	0	0	0	0	0	0	0	**0**
1993 (Jul. 5)	2	100	0	0	0	0	0	0	0	0	**0**
Kemptville (OMAFRA Station)											
1991 (Jul. 15)	14	0	92.9	7.1	0	0	4.6	1.8	0	0	**6**
1992 (Jul. 15)	8	100	0	0	0	0	0	0	0	0	**0**
1993 (Jul. 13)	14	100	0	0	0	0	0	0	0	0	**0**

* Injury index scores were derived by multiplying the percentage (decimal) values by the following corresponding weighting factors - trace (x 5); light (x 25); moderate (x 50) and severe (x 100). The total injury index score for each location/year was the sum of all injury indices. For example, if 30% of obs. fell in trace (0.3 x 5 = 1.5), and 30% in light (0.3 x 25 = 7.5), the total injury index score would be 1.5 + 7.5 = 9, out of a maximum 100. ** Values have been rounded off to nearest whole number.

Table 9: Ambient Ozone Concentrations Recorded in July and August Prior to White Bean Surveys: 1991-1994.

Air Monitor/ Year/Date of Survey	Ambient Ozone Concentration (ppb)(based on a 10am-4pm 7 hr. day)*						
	Month of JULY			Month of AUGUST			Total hrs. 80 ppb or more
	Mean conc.	Max. conc.	No. hrs. 80 ppb or more	Mean conc.	Max. conc.	No. hrs. 80 ppb or more	
Windsor (Harrow CDA Station)**							
1991 (Aug. 27)	46	99	15	35	79	0	15
1992 (Aug. 25)	28	82	1	34	79	0	1
1993 (Aug. 27)	41	74	0	41	92	7	7
1994 (Aug. 31)	37	82	1	26***	63***	0***	1***
Parkhill (Huron Park OMAFRA Station)**							
1991 (Aug. 28)	50	117	22	41	110	9	31
1992 (Aug. 25)	36	69	0	41	78	0	0
1993 (Aug. 24)	43	96	2	43	73	0	2
1994 (Aug. 30)	45	93	3	43	96	6	9
Merlin (Ridgetown OMAFRA Station)**							
1991 (Aug. 27)	53	114	24	42	87	4	27
1992 (Aug. 24)	36	61	0	37	79	0	0
1993 (Aug. 22)	40	79	0	43	82	2	2
1994 (Aug. 30)	41	77	0	40	89	2	2
Guelph (Elora University Station)**							
1991 (Aug. 28)	51	113	22	41	89	4	26
1992 (Aug. 26)	33	64	0	35	69	0	0
1993 (Aug. 24)	39	71	0	58	73	0	0
1994 (Aug. 30)	41	65	0	41	83	3	3

* For period ending on day preceding survey date. ** Air monitor closest to white bean station shown in parenthesis.
*** Data was missing for 13 days because of instrument failure.

Table 10: Ambient Ozone Concentrations Recorded in June and July Prior to Tomato/Potato Surveys: 1991-1993.

Air Monitor/ Year/Date of Survey	Ambient Ozone Concentration (ppb)(based on a 10am-4pm 7 hr day)*						
	Month of JUNE			Month of JULY*			Total hrs. 80 ppb or more
	Mean conc.	Max. conc.	No. hrs. 80 ppb or more	Mean conc.	Max. conc.	No. hrs 80 ppb or more	
Windsor (Herrow CDA Station)**							
1991 (Jul. 10)	44	94	14	46	95	2	16
1992 (Jul. 7)	41	103	8	37	71	0	8
1993 (Jul. 7)	32	91	8	41	74	0	8
Merlin (Ridgetown OMAFRA Station)**							
1991 (Jul. 10)	54	109	29	52	84	1	30
1992 (Jul. 8)	44	92	6	36	59	0	6
1993 (Jul. 6)	36	105	5	48	73	0	5
London (University Station near Ilderton)**							
1991 (Jul. 9)	50	97	10	52	85	4	14
1992 (Jul. 7)	43	93	5	33	53	0	5
Simcoe (Simcoe OMAFRA Station)**							
1991 (Jul. 11)	48	79	0	47	69	0	0
1992 (Jul. 9)	47	106	9	30	46	0	9
1993 (Jul. 8)	45	88	7	57	85	2	9
Kitchener (Cambridge OMAFRA Station)**							
1991 (Jul. 9)	51	118	12	49	66	0	12
1992 (Jul. 7)	42	86	2	31	48	0	2
1993 (Jul. 7)	42	92	4	20	76	0	4
Stouffville (Kettleby OMAFRA Station)**							
1991 (Jul. 8)	42	106	2	34	66	0	2
1992 (Jul. 6)	39	83	3	29	38	0	3
1993 (Jul. 5)	36	73	0	41	50	0	0
Peterborough (Smithfield CDA Station)**							
1991 (Jul. 15)	41	95	9	36	61	0	9
1993 ((Jul. 13)	18	61	0	27	60	0	0
Ottawa (Kemptville OMAFRA Station)**							
1991 (Jul. 15)	36	67	0	32	57	0	0
1992 (Jul. 15)	21	69	0	20	40	0	0
1993 (Jul. 13)	28	76	0	38	73	0	0

* For period ending on day preceding the survey date ** Air monitor closest to tomato/potato station shown in parenthesis
Note Peterborough ozone monitor was not operated in 1992